DOCUMENT RESUME

ED 350 133 RC 018 812

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TITLE Rural/Nonrural Differences among Secondary Science Teachers: Evidence from the Longitudinal Study of American Youth.
INSTITUTION Consortium for Policy Research in Education, New Brunswick, NJ.
SPONS AGENCY Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE Apr 92
CONTRACT R1178G10039
NOTE 22p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, CA, April 3-7, 1992).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Mathematics Education; *Rural Urban Differences; *Science Education; *Science Teachers; Secondary Education; State Standards; *Teacher Certification; *Teacher Characteristics; Teacher Education; Teacher Qualifications; Teaching Experience
IDENTIFIERS Longitudinal Study of American Youth

ABSTRACT

This paper examines rural/nonrural differences in the secondary science teachers' work force, using data from the Longitudinal Study of American Youth. The national probability sample included 456 middle or secondary science teachers from 93 schools. T-tests and multivariate analyses were used in the study. Relative to their nonrural colleagues, rural teachers are less experienced, more likely to have taught subjects other than science, more likely to have majored in education, less likely to have majored in a science, and less likely to have a graduate degree. Rural teachers report having taken fewer science courses and fewer science methods courses at both the undergraduate and graduate levels. The paper explores the interaction of ruralness, educational training, and state certification requirements on science teachers. Little rural/nonrural difference is attributable to state-by-state differences in teacher certification requirements. Rural teachers report having taken fewer subject-matter courses than their nonrural colleagues, a difference that persists when the effects of undergraduate major, graduate training, and state differences in certification policy are removed. Three policy remedies are examined. The paper suggests that further efforts be made to help states clarify and choose appropriate policy responses. (Author/TES)

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Rural/Nonrural Differences among Secondary Science Teachers: Evidence from the Longitudinal Study of American Youth

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ABSTRACT

This paper describes rural/nonrural differences in the secondary science teaching work force, using data from the Longitudinal Study of American Youth. Relative to their nonrural colleagues, rural teachers are less experienced, more likely to have taught subjects other than science, more likely to have majored in education, less likely to have majored in a science, and less likely to have a graduate degree. Rural teachers report having taken fewer science courses and fewer science methods courses, at both the undergraduate and graduate levels. We explore the interaction of ruralness, educational training, and state certification requirements on teachers using multivariate analysis. Some, but not all, of the rural/nonrural difference is attributable to state-by-state differences in teacher certification requirements. For example, rural teachers report having taken fewer subject-matter courses than their nonrural colleagues, a difference that persists when the effects of undergraduate major, graduate training, and state differences in certification policy are removed. Our analysis uses a 1988 national sample of 456 teachers from 93 schools, part of an ongoing longitudinal study of science and mathematics education.

Perspective

We conducted this analysis to provide background information for two different projects, one a study of educational productivity and the other a study of science teacher misassignment in rural secondary schools. This research is consequently guided by both an interest in the predictive utility of school-level variables in educational production functions and by a

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[1] This paper has been prepared as part of the research of the Finance Center of the Consortium for Policy Research in Education (CPRE), a consortium of the University of Southern California, Rutgers University, Cornell University, Harvard University, Michigan State University, Stanford University and the University of Wisonsin-Madison. The work was supported by grant #R1178G10039 from the U.S. Department of Education, Office of Educational Research and Improvement. The views expressed are those of the authors and are not necessarily shared by USC, CPRE, or its partners, or the U.S. Department of Education. Correspondence may be addressed to either author at the Department of Education, Kennedy Hall, Cornell University, Ithaca, NY 14853. This paper was presented at the annual meeting of the American Educational Research Association, San Francisco, CA, April 20-24, 1992.

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sensitivity to the challenges that rural schools face in recruiting and retaining science teachers.

Recent research on teacher subject matter knowledge in science suggests that teacher knowledge has important consequences for the ways in which classrooms and curricula are organized. For example, subject-matter deficiencies may prevent teachers from implementing a conceptual change model of teaching (Hollon, Roth, & Anderson, 1991), a widely-taught science teaching strategy. Subject-matter knowledge appears to affect the ways in which science teachers plan activities, manage classroom conversations, and question students (Carlsen, 1991). To date, however, explorations of the effects of teacher knowledge on science teaching have been largely restricted to intensive studies of small numbers of teachers, and little is known about the long-term consequences of teacher knowledge on student learning. Educational productivity research can use statistical techniques to sort out the relative contributions of teacher knowledge and other variables using large datasets (Monk, 1991). As a tool in policy deliberation, productivity research offers techniques for gauging the relative effects of isolation, school size, teacher attributes, and other factors on the achievement of rural students.

Methods

Our analysis uses teacher data from the Longitudinal Study of American Youth (LSAY), a National Science Foundation-funded study centered at the Public Opinion Laboratory at Northern Illinois University (Miller, Suchner, Hoffer, Brown, & Pifer, 1991). The LSAY data are a potentially valuable resource because they provide both fine-grained details on science teachers' educational training (e.g., course counts by science subject-matter area) and the opportunity to trace the effects of these measures on student performance over a multi-year period. We used Release 2 of the teacher data file, made available in 1990. The sample of 456 middle and secondary science teachers

from 49 schools is a national probability sample, stratified by region and community type (urban, suburban, rural).

The analysis we report here proceeded in two phases. First, we documented rural/nonrural differences on all variables that measured teacher education and experience. As we will show, this revealed a consistent pattern of differences. We became suspicious that these differences might actually reflect the confounding influence of state variation in teacher certification requirements; this suspicion was supported when, leaving the LSAY data for a moment, we graphed population density for each of the 50 states (Bureau of the Census, 1986) by state provisional teacher certification requirements (Blank, 1988) and found that state population density was a reasonably good predictor of teacher certification requirements (see Figure 1). Subsequently, we contacted LSAY and were given the state identifications for each of the schools in the sample, information that is not otherwise included in the data releases. Using Blank's (1988) summary of state certification policies, we added a new variable to the LSAY data file, Bio87Cer, a continuous variable (range 0-45 credit hours) that reflected the state's initial teacher certification subject-matter course requirement for biology teachers. This variable functions in our study as a proxy measure of state certification policy.[2]

The second phase of analysis explored the implications of state certification policies for inequities between rural and nonrural schools. To do this analysis, we focused on an illustrative and continuously distributed

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[2] Obviously, state certification policy includes much more than the number of credit hours required for biology certification. This particular variable has some advantages over other measures, however. For example, unlike requirements concerning advanced degrees, it is a continuous variable, yielding a range adequate for regression analysis. Biology as an "indicator subject" has the advantage that almost every state has a biology teaching certificate; some states collapse chemistry and physics into a single physical science certification area, complicating comparison of the requirements in different states.

measure of teacher preparation, TotSciMa, the total science/mathematics course counts reported by teachers for both undergraduate and graduate study. Our analysis asked, using regression models, how well do ruralness, graduate degree status, undergraduate major, and state certification policy predict this outcome measure? Are rural/nonrural differences simply an artifact of laxer certification requirements in states that are primarily rural?

Results

In the first phase, we identified a consistent pattern of rural-nonrural differences on a wide variety of science teacher characteristics. We were surprised to find few differences between urban and suburban teachers: On most measures, urban and suburban teachers resembled each other much more than they resembled their rural colleagues. In order to increase statistical power, in the analyses that follow we contrast rural teachers with the combined urban-suburban groups.

Table 1 summarizes rural-nonrural differences on a number of variables. For measures that are continuous and normally distributed, significance of rural-nonrural differences is gauged using a t-test of independent groups. For measures that are dichotomous or non-normal, we use the Mann-Whitney U statistic, a robust nonparametric test.

Teaching experience. Relative to their nonrural colleagues, rural science teachers have significantly less experience (a) teaching science, (b) teaching in their current school district, (c) teaching in their current school building, and (d) teaching any subject anywhere. Rural teachers have a mean of 14.3 years of science teaching experience, for example, 3.1 years less than their nonrural colleagues ($p=.001$).

Non-science teaching. Despite their relative inexperience, rural teachers report more years of teaching during which they had no science assignment: a mean 2.5 years compared to 2.0 years for nonrural teachers. Proportionally, rural

teachers reported a mean 81% of their years of teaching experience included at least one science assignment, compared to 87% for nonrural teachers (p=.008).

Advanced degrees. Rural teachers were significantly less likely to have a degree beyond the bachelor's degree. Of the entire sample, 48% of rural teachers and 65% of nonrural teachers reported advanced degrees. Some of this difference is attributable to rural teachers' relative inexperience. However, when our sample is stratified by years of teaching experience, significant rural-nonrural differences are seen only for experienced teachers, those with 10-15 years of teaching experience and those with over 15 years of experience.

Undergraduate major. Rural teachers are significantly more likely to report that they majored in education as undergraduates (p=.045). Although fewer rural teachers (48%) than nonrural teachers (57%) report majoring in a science, the difference is not statistically significant using a nonparametric test. Nevertheless, we are fairly confident that the difference is real. For example, when a large number of teachers were removed from the dataset on the grounds that their reported course counts were implausible (described below and in Note 4), both the remaining sample size and the percent of teachers reporting science majors drops. Of the 360 teachers whose course counts were judged plausible and who named an undergraduate major, 42% of rural teachers and 54% of nonrural teachers reported science majors. This difference is significant, using a non-parametric test (Mann Whitney U, p=.04).

Time since completing undergraduate degree. Although the difference was not significant, rural teachers received their bachelor's degrees about 1.5 years more recently than nonrural teachers (mean 17.1 yrs ago for rural teachers vs. 18.6 years ago for nonrural teachers). Curiously, this difference is about half the rural-nonrural difference in teaching experience, suggesting that either rural teachers were more likely to be certified at the master's degree level (implausible, given their reduced likelihood of having a master's degree) or were

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more likely to take time off from teaching at some point during their career. The latter pattern might occur if, for example, rural teachers were more likely to take time off from teaching to pursue other careers or care for their families. The LSAY data are not suitable for exploring these possibilities, however.[3]

Course taking. Table 2 summarizes rural/nonrural differences in teachers' self-reported course-taking. The table uses a subset of 351 teachers in the sample whose reported coursework was judged plausible. The extreme and methodologically problematic decision to drop almost a quarter of our sample reflects a problem in the LSAY dataset that appears to be due to the fact that although teachers were asked to report course counts, many appear to have reported credit hours.[4]

Using this subset of teachers, we found that rural teachers reported significantly fewer undergraduate science courses and significantly fewer undergraduate science methods courses than their nonrural colleagues. Rural teachers report significantly less combined undergraduate science and mathematics

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[3] The teacher questionnaire, for example, does not ask teachers to report their gender.

[4] This part of the analysis proceeded in two phases. First, we converted quarter-hour courses to semester-hour course equivalents for all teachers using the formula (Semester_hour_equiv = 0.75 x Quarter_hour_count). So, for example, 4 quarter-hour courses would be recoded as 3 semester-hour courses for a given teacher. Using that somewhat-arbitrary conversion factor, mean course counts for teachers who reported semester-hour courses were found to be very similar to mean counts for teachers who reported quarter-hour courses.

Inspection of the resulting course counts showed that a large number of teachers reported implausible patterns of undergraduate courses. Unfortunately, there is no unbiased way to make judgments about which teachers reported credit hours and which reported course counts. Some filtering out of suspect cases seemed essential, however, because otherwise mean course counts clearly would be inflated. Therefore, we developed a set of decision rules to flag (and subsequently remove from the course count analysis) teachers whose course counts could be consistently identified as implausible. Rather than convert reports to course counts (e.g., by dividing them by 3 or 4), we simply dropped these cases from this part of the analysis. This step is obviously methodologically troublesome.

We flagged and removed any teacher who reported (1) more than 40 undergraduate science courses, (2) more than 25 undergraduate science or math methods courses, (3) more than 25 graduate science or math methods courses, (4) fewer than 10 courses in science and mathematics and a major in a science, or (5) more than 30 science and mathematics courses and more than 20 methods courses.

We should note that the pattern of rural/nonrural differences in course counts that we report here persists even when suspect cases are not filtered out of the dataset. The mean course counts of the whole sample, however, are higher and probably more biased.

coursework than nonrural teachers, a difference that persists even when only individuals with advanced degrees are included in the analysis (eliminating teachers who have taken some graduate courses but not received a master's degree). In addition, a consistent pattern of non-significant differences occurred for other measures, including undergraduate mathematics, graduate science, graduate mathematics, and graduate science methods.

We were mildly surprised by the difference in science methods courses, anticipating that, overall, the relative prevalence of the education majors in rural schools would be coupled with lower science course counts but higher science methods course counts. We found the former to be true but not the latter.

Multivariate models for assessing the effects of state certification policy. The second phase of our analysis was undertaken to determine to what extent state teacher certification policy accounted for observed rural/nonrural differences in teacher attributes. To do this, we turned to a multiple regression framework, and estimated the relative contributions of three variables on the TOTSCIMA outcome measure (total science/math course counts). Our choice of outcome measure was determined in part by the fact that course counts are a common part of state certification policy and in part by statistical characteristics of the variable in this dataset.[5]

Our first regression predicted main effects on TOTSCIMA by RURAL (1=rural, 0=nonrural), HAVEMAST (1=has master's degree, 0=no master's degree), and REALSCI (1=undergraduate science major, 0=no undergrad science major). All three dichotomous independent variables contributed significant main effects. We then added BIO87CER, the state certification policy proxy (range 0-45 credit hours of science required for biology teacher certification in 1987). Adding the policy

[5] Bio87Cer is a normally-distributed measure with a wide range. We need to emphasize that our point here is to tease out the relative contributions of ruralness and state certification policy. We do not want to suggest that this is the best outcome measure: It is relevant to policy deliberations but more indicative of overall state policy than comprehensively descriptive.

variable had little effect on the regression. RURAL showed a negative influence on the outcome, HAVEMAST and REALSCI showed a positive effect, and BIO87CER had no effect. Table 3 summarizes this model, using the subset of non-suspect cases.[6]

We were surprised to find no effect by BIO87CER, given our preliminary finding (Figure 1), which linked state population density and state certification policy. Following the recommendation of Jaccard, Turrisi, and Wan (1990), we divided our sample into three groups (low, medium, and high values of BIO87CER) and constructed separate graphs of the effects of our independent measures on TOTSCIMA for each group. These graphs revealed interactions between BIO87CER and the other independent measures. In response to this, we included first-order interactions in our second regression model (Table 4), which improved the overall performance of the model (as seen in the squared multiple R). Unfortunately, it also introduced a multicollinearity problem (reflected in low reported tolerances). Therefore, we dropped the two non-significant interaction terms and produced our final model (Table 5).

Table 5 shows significant main effects on science/mathematics coursework by RURAL (negative), HAVEMAST (positive), and REALSCI (positive), a significant interaction effect for HAVEMAST x BIO87CER, and no main effect by BIO87CER. (The interaction effect can be interpreted in this fashion: The positive contribution of a graduate degree on the outcome measure is significantly reduced if a teacher resides in a state with rigorous certification requirements.) The model does not perform as well for the larger dataset--which includes suspect cases--because of the influence of erroneous course counts.

In our judgment, the third model (Table 5) provides the best estimates of the effects of rural location, graduate degree status, undergraduate major, and state certification policy on the TOTSCIMA outcome measure.

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[6] Our strategy is to find the best regression model using the smaller, less suspect dataset. Later, we will apply the model to the original dataset, which includes suspect cases.

Discussion and Policy Implications

Our paper contains four major results. First, there are significant rural/nonrural differences with respect to traditional indicators of teacher educational preparation. For example, we found that, relative to their nonrural colleagues, rural teachers were less likely to have a graduate degree and were less experienced.

Second, there are significant rural/nonrural differences in indicators that are receiving attention from policy makers as appropriate gauges of educational quality. New datasets like LSAY make it possible to differentiate among teachers on the basis of detailed information about subject-matter preparation. Taking advantage of these new analytical capabilities, we found significant differences between rural and nonrural teachers in their teacher education programs. Specifically, we found that rural science teachers were less likely to have majored in science and report having taken fewer science and mathematics courses.

Third, significant rural/nonrural differences in teacher preparation persist in the face of controls for other attributes, at both the individual teacher and state levels. These differences remain when controls are included for both teachers' undergraduate major and graduate degree status. A rural effect persists when controls are established for differences among states in the requirements they impose for provisional teacher certification. This means that the rural/nonrural difference in teacher preparation cannot be explained solely in terms of differences among the states in the level of their requirements for licensure.

Fourth, there is no direct relationship between state requirements for certification and the course preparations of teachers. An interaction effect was found, however, between state certification requirements and teachers' graduate degree status. Specifically, in states with relatively strict

certification requirements, having a master's degree is less strongly related to the number of math and science courses in a teacher's background than is the case in states with lax certification requirements. One theoretical interpretation of this finding is that the impact of state certification policy is indirect--a weak independent predictor of teachers' course-taking but a good predictor of teachers' level of educational attainment.

Collectively, these findings indicate that ruralness is negatively related to some key measures of schooling quality. Before turning to the policy implications of this result, several caveats need to be noted. For example, we must be mindful of the fact that teacher characteristics are a very indirect measure of school quality. Our findings would be more compelling if we could show that attributes like teaching experience, degree level, undergraduate major, and science course-taking were dependably linked to subsequent pupil performance.[7]

We must also be mindful of what we have not been able to control for in our analysis. In particular, we know that in many places, ruralness is associated with poverty. What appears to be a rural effect in this paper may in fact be an economic effect. We have also not tried to disentangle rural effects from school size effects. We have more to say about the size/rural mixing later.

These caveats are important and temper the sweep of the policy implications we can derive based on our available evidence. It is nevertheless useful to consider what the policy implications would be of a finding that ruralness per se is associated with lower levels of schooling quality for students. In the following discussion, we explore several

[7] For work in progress where the focus is on estimating relationships between the content preparation of science teachers and the subsequent performance of pupils, see Monk (1991).

alternative policy responses, and point out the importance of developing a coherent means of choosing one in preference to another.

#1. Provide compensatory assistance based on ruralness. Ruralness in this context is looked at as an indicator or barometer of difficulties in assembling a high quality faculty. Whether ruralness is the cause is less important than the presumption that it flags a possible difficulty.

In the present context, a useful distinction can be drawn between incumbent and future teachers. For the incumbents, the state might offer incentives for teachers to upgrade their backgrounds in mathematics and science. These incentives might be offered to school districts (e.g., districts could receive additional funds with the expectation that they be used to assist teachers in upgrading their training), or they might go directly to teachers, as summer tuition grants, for example. In either case, there could be some outcome measure to which recipients would be held accountable. For example, if the district received the funds, it could be expected to demonstrate increases in its teachers' credentials.

For future teachers, the state might intervene to increase the minimum requirements for hiring in certain districts. A rural school district might be enjoined from hiring new teachers with certain credentials (e.g., provisionally-certified teachers with minimal subject-matter preparation), for example, unless it could demonstrate that the rest of its faculty was well prepared. Such a regulation would provide an incentive for schools to upgrade the credentials of existing faculties, as well as discourage hiring underprepared teachers to join already-weak faculties. Financial assistance to rural districts might be necessary to make it possible for them to hire teachers with the higher credentials. Nevertheless, targeting stricter teacher preparation requirements to weaker districts would probably cost less in the

long run than raising certification requirements for all teachers across the board.

#2. Eliminate the source of the rural schools' difficulties. The second policy response is quite different from that sketched above. Instead of trying to remedy whatever deficiencies are found in rural schools, the goal would be to eliminate the effects of the difficulty. Rather than try to correct weak teacher credentials in rural schools, we might eliminate rural schools, or at least eliminate that portion of "ruralness" which gives rise to the problem. Obviously, caught up in this view is a difficulty that stems directly from the "rural" construct. Ruralness can mean many things, and we do not know what it is about ruralness that gives rise to the inequalities we document in this paper.

For example, rural schools are often small. If weaker teacher credentials are in fact related to small size rather than to ruralness, one could use district and school reorganization policies to eliminate the source of the inequalities. Schools would still exist in rural areas, but in a post-reorganization world, inequalities in teacher preparation might eventually disappear. Alternatively, weaker teacher credentials might be more directly related to per-pupil expenditures than ruralness. Broader reforms in school finance or community development might be the only way to ameliorate the inequity. Our analysis does not attempt to disentangle these effects. That would be a fruitful extension of what we do accomplish here, and the results would be quite relevant for policy.

#3. Wait it out. According to this view, the relatively low levels of teacher preparation that exist in rural schools are either above minimum state requirements (and are therefore not of concern) or result from laxity or lags in enforcement of existing standards. We suspect that much of the effect we have described can be attributed to grandfathering when new certification

requirements were put into place by state education departments in the 1970s and 1980s. This explanation would account for the many experienced teachers in our sample who do not have master's degrees and who are teaching in states that now require master's degrees for permanent certification. Eventually, these teachers will retire and be replaced by better-credentialed individuals. Nevertheless, as states continue to change certification requirements, it is worth exploring whether grandfathering clauses have disproportionate effects on rural schools. For example, some grandfathered teachers might elect to continue their higher education if their schools were not located in isolated areas or if courses could be provided using distance learning technologies.

Conclusion

We have presented evidence suggesting that the educational preparation of science teachers in rural schools is more limited than that of teachers working in urban and suburban schools. The increasing attention that teacher preparation is receiving from people concerned with educational productivity underscores the significance of our findings. We have also sketched three--inconsistent--policy remedies and noted that states have yet to devise a principled means of choosing one approach over another.

The inequalities we document in this paper are substantial and potentially alarming. An obvious next step is further work to measure them more precisely and, more importantly, explore their implications for student learning. Further efforts to help states clarify appropriate policy responses is also needed.

Table 1.

Differences Between Rural and Nonrural Teachers

Teacher Characteristic	Rural mean	Nonrural mean	Difference[8]
Teaching experience (science only)	11.2 yrs	14.3 yrs	p=.001; U
Teaching experience (in this district)	10.1 yrs	13.7 yrs	p=.001; U
Teaching experience (in this building)	8.2 yrs	10.1 yrs	p=.022; U
Teaching experience (of any kind)	13.7 yrs	16.3 yrs	p=.006; U
Proportion of teaching experience that is science teaching	0.81	0.87	p=.008; U
Teachers having degrees beyond bachelor's	48.2%	64.7%	p=.002; U
Teachers having degrees beyond bachelor's (teachers with 10-15 years experience)	52.4%	81.1%	p=.01; U
Teachers having degrees beyond bachelor's (teachers with over 15 years experience)	55.7%	79.1%	p=.01; U
Teachers reporting undergraduate majors in education	48.0%	36.9%	p=.045; U
Teachers reporting undergraduate majors in a science	48.0%	57.0%	n.s.; U
Time since completing undergraduate degree	17.1 yrs	18.6 yrs	n.s.; U
Number of teachers (maximum per cell)	108	348	

[8] U = Mann Whitney U, a non-parametric test. t = t-test for independent groups.

Table 2.

Differences Between Rural and Nonrural Teachers in Coursework.

Teacher Characteristic	No. of courses taken: Rural mean	Nonrural mean	Significance of Difference (t-test)
Reported undergraduate science courses[9]	15.0	18.5	p=.001
Reported undergraduate mathematics courses	2.9	3.4	n.s.
Reported undergrad science methods courses	0.9	1.6	p=.003
Reported graduate science courses (teachers with advanced degrees only)	7.0	9.0	n.s.
Reported graduate mathematics courses (teachers with advanced degrees only)	0.8	0.7	n.s.
Reported graduate science methods courses (teachers with advanced degrees only)	1.6	2.1	n.s.
Total science and mathematics coursework, undergrad and grad (all teachers)	18.9	23.9	p=.001
Total science and mathematics coursework (teachers with advanced degrees)	21.6	25.5	p=.04
Total secondary science methods coursework (teachers with advanced degrees)	2.5	3.2	n.s.
Number of teachers (maximum per cell)	78	273	
Number of teachers with advanced degrees who report coursework counts	32	141	

[9] The means presented in this table are for a subset of teachers whose course-taking reports were judged plausible, using a set of rules detailed in Appendix A. Although means for the entire sample of 456 teachers are higher than shown here, they show the same pattern of rural-nonrural differences.

Table 3.

Multivariate Model 1: Predict Science and Math Coursework, Main Effects Only

(Excluded SUSPECT cases. 69 CASES DELETED DUE TO MISSING DATA.)

DEP VAR:TOTSCIMA N: 317 MULTIPLE R: 0.472 SQUARED MULTIPLE R: 0.223
ADJUSTED SQUARED MULTIPLE R: 0.213 STANDARD ERROR OF ESTIMATE: 10.41

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	16.43	2.26	0.00	.	7.27	0.00
RURAL	-3.07	1.45	-0.11	0.97	-2.12	0.03
HAVEMAST	4.08	1.24	0.17	0.95	3.28	0.00
REALSCI	9.28	1.21	0.40	0.94	7.68	0.00
BIO87CER	-0.01	0.07	-0.01	0.92	-0.15	0.88

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	9722.38	4	2430.59	22.41	0.00
RESIDUAL	33836.80	312	108.45		

Table 4.

Multivariate Model 2: Add Interactions with State Policy Variable

(Add interactions with BIO87CER. ExcludedSUSPECT case. 69 CASES MISSING DATA.)

DEP VAR:TOTSCIMA N: 317 MULTIPLE R: 0.497 SQUARED MULTIPLE R: 0.247
ADJUSTED SQUARED MULTIPLE R: 0.229 STANDARD ERROR OF ESTIMATE: 10.31

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	5.76	4.24	0.00	.	1.36	0.18
RURAL	0.35	5.28	0.01	0.07	0.07	0.95
HAVEMAST	14.92	4.44	0.62	0.07	3.36	0.00
REALSCI	16.93	4.49	0.72	0.07	3.77	0.00
BIO87CER	0.37	0.15	0.27	0.22	2.53	0.01
RURAL*						
BIO87CER	-0.12	0.17	-0.13	0.07	-0.70	0.49
HAVEMAST*						
BIO87CER	-0.37	0.15	-0.53	0.06	-2.57	0.01
REALSCI*						
BIO87CER	-0.26	0.14	-0.37	0.06	-1.79	0.07

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	10739.04	7	1534.15	14.44	0.00
RESIDUAL	32820.13	309	106.21		

Table 5.

Multivariate Model 3: Dropped Non-significant Interaction Terms

(69 CASES DELETED DUE TO MISSING DATA.)

DEP VAR:TOTSCIMA N: 317 MULTIPLE R: 0.488 SQUARED MULTIPLE R: 0.238
ADJUSTED SQUARED MULTIPLE R: 0.226 STANDARD ERROR OF ESTIMATE: 10.33

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	10.35	3.32	0.00	.	3.12	0.00
RURAL	-3.22	1.44	-0.11	0.97	-2.24	0.03
HAVEMAST	14.64	4.42	0.60	0.07	3.31	0.00
REALSCI	9.16	1.20	0.39	0.94	7.65	0.00
BIO87CER	0.21	0.11	0.15	0.36	1.84	0.07
HAVEMAST* BIO87CER	-0.36	0.14	-0.51	0.06	-2.48	0.01

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	10380.79	5	2076.16	19.46	0.00
RESIDUAL	33178.38	311	106.68		

Table 6.

Multivariate Model 4: Use Entire Dataset, including Suspect Cases

(73 CASES DELETED DUE TO MISSING DATA.)

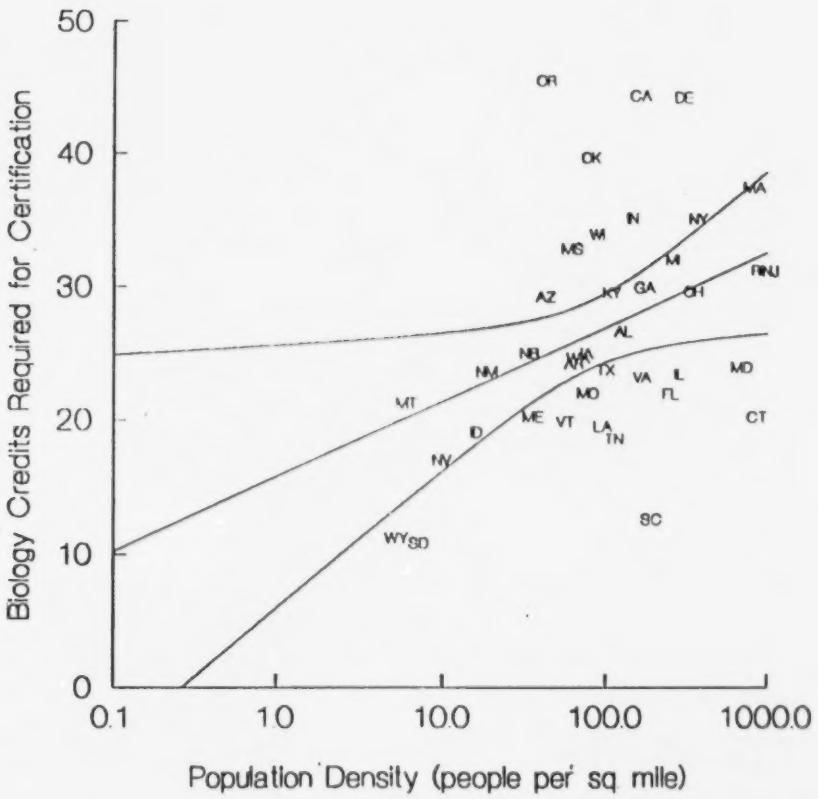
DEP VAR:TOTSCIMA N: 383 MULTIPLE R: 0.464 SQUARED MULTIPLE R: 0.215
ADJUSTED SQUARED MULTIPLE R: 0.204 STANDARD ERROR OF ESTIMATE: 15.54

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	16.44	4.31	0.00	.	3.82	0.00
RURAL	-2.19	1.95	-0.05	0.96	-1.12	0.26
HAVEMAST	14.80	5.92	0.42	0.08	2.50	0.01
REALSCI	14.96	1.63	0.43	0.96	9.20	0.00
BIO87CER	0.05	0.15	0.02	0.40	0.34	0.74
HAVEMAST* BIO87CER	-0.37	0.19	-0.35	0.06	-1.91	0.06

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	24912.04	5	4982.41	20.64	0.00
RESIDUAL	91007.41	377	241.40		

Figure 1. Population Density by Teacher Certification Requirements for the 50 states.



Regression of Bio87Cer (min. biology coursework for certification) and LogDense (base 10 log of state population density):

DEP VAR:BIO87CER N: 39 MULTIPLE R: .380 SQUARED MULTIPLE R: .144
ADJUSTED SQUARED MULTIPLE R: .121 STANDARD ERROR OF ESTIMATE: 8.076

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	15.749	4.418	0.000	.	3.564	0.001
LOGDENSE	2.413	0.967	0.380	1.000	2.496	0.017

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	406.423	1	406.423	6.231	0.017
RESIDUAL	2413.436	37	65.228		

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